

Computational Fluid Dynamics based
Extraction of Heat Transfer Coefficient in Cryogenic Propellant Tanks

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Current reduced-order thermal model for cryogenic propellant tanks is based on correlations built for flat plates collected in the 1950's. The use of these correlations suffers from: inaccurate geometry representation; inaccurate gravity orientation; ambiguous length scale; and lack of detailed validation. The work presented under this task uses the first-principles based Computational Fluid Dynamics (CFD) technique to compute heat transfer from tank wall to the cryogenic fluids, and extracts and correlates the equivalent heat transfer coefficient to support reduced-order thermal model.

The CFD tool was first validated against available experimental data and commonly used correlations for natural convection along a vertically heated wall. Good agreements between the present prediction and experimental data have been found for flows in laminar as well turbulent regimes. The convective heat transfer between tank wall and cryogenic propellant, and that between tank wall and ullage gas were then simulated. The results showed that commonly used heat transfer correlations for either vertical or horizontal plate over predict heat transfer rate for the cryogenic tank, in some cases by as much as one order of magnitude.

A characteristic length scale has been defined that can correlate all heat transfer coefficients for different fill levels into a single curve. This curve can be used for the reduced-order heat transfer model analysis.